Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

DENSITY SENSOR FOR SOLIDS COMPONENT IN TWO PHASE FLOW

J.K. Szymanski and N.A. Mansour

January 1986

...ected
...ed primarily
...ion and internal
...poses. It does not
...final expression of
the opinions of the Canada Centre
...ot and Energy Technology
(CANMET)

Ce document ... publication
provincial ... reviewé et ... exigé
pour ... au sein de
di... et ... document ne
re... ... ne doivent
m... ... définitive de
l'... ... Canada Centre de
t... ... des minéraux et de
l'... (CANMET)

10 pp

ENERGY RESEARCH PROGRAM
COAL RESEARCH LABORATORIES
DIVISION REPORT ERP/CRL 86-8(TR)

MICROMEDIA
APR 23 1986

DENSITY SENSOR FOR SOLIDS COMPONENT IN TWO PHASE FLOW

by

J.K. Szymanski* and N.A. Mansour*

ABSTRACT

This report presents a new sensor for on-line measurement of the density of solids in a slurry. The sensor comprises three instruments, for measuring 1) the total volumetric flow rate, 2) the total mass flow rate and 3) the volume fraction of water in the slurry. Three simultaneous equations characterizing the output of the three instruments are solved using a simple computer propgram stored in a microprocessor to give the density of the ty of solids in the slurry.

* Research Scientists, Energy, Mines and Resources Canada, CANMET, Edmonton, Alberta, Canada

CAPTEURS POUR MESURER LA DENSITÉ DES CONSTITUANTS SOLIDES DANS LES DÉBITS À DEUX PHASES

par

J.K. Szymanski* et N.A. Mansour*

RÉSUMÉ

Dans ce rapport, les auteurs présentent un exposé sur un nouveau capteur utilisé pour mesurer en direct la densité des constituants solides d'un coulis. Le capteur comprend trois instruments servant à mesurer 1) le débit volumétrique total, 2) le débit massique total et 3) le volume de la fraction d'eau dans le coulis. Trois équations simultanées caractérisant le rendement des trois instruments sont résolues au moyen d'un programme machine simple enregistré dans un microprocesseur afin de donner la densité des constituants solides du coulis

*Chercheurs scientifiques, Énergie, Mines et Ressources Canada, CANMET, Edmonton (Alberta) Canada.

CONTENTS

	Page
ABSTRACT	i
RESUME	ii
INTRODUCTION	1
THEORY OF OPREATION	1
CONCLUSIONS	2
REFERENCES	3

FIGURES

No.		
1.	Schematic diagram of solid density sensor system	5

INTRODUCTION

A density sensor is under development for application in the hydraulic transport of two phase mixtures (liquids and solids) flowing in a pipe. The sensor utilizes a magnetic flow meter, micro motion mass flow meter and one of either rotating field conductance gauge, a normal conductivity meter or a capacitance meter (1,2,3,10). The sensor is intended for use with the mobile field testing units, of the Edmonton Coal Research Laboratory for accurately measuring the solids loading at major points in the process (11, 12). Instrumentation capable of accurately determining the solids content is vital to the success of the mobile plant programs. To the author's knowledge, no attempts have previously been made to measure the density of solids in a slurry using the proposed setup. To date it has only been possible to measure the pulp density of a slurry. Knowledge of the solids distribution at critical points in the circuitry will enable us to compare directly the performance of the various process options. Based on an empirical correlation between coal density and ash content the sensor system can be used for continuously monitoring the ash content of the coal being transported in coal/water slurry [4,5,6,7,9] pipelines.

THEORY OF OPERATION

A schematic diagram of the three component density sensor is shown in Fig.1. The magnetic flow meter measures the total volumetric flow rate of slurry, the micro-motion mass flow meter measures the total mass flow rate, and the conductivity gauge measures the volume fraction ot the water phase.

Outputs of the three gauges can be expressed as three simultaneous equations whose solution, readily obtained using a microprocessor,yields the solids density.

From the magnetic flow meter, total volumetric flow rate of slurry (Q_v)is given by

$$Q_V = Q_L + Q_S \tag{1}$$

Where Q_L= volumetric flow rate of liquid, [m^3/s] and Q_S= volumetric flow rate of solids, [m^3/s]

From the Conductivity sensor volume fraction (ϕ_L) of the conductive liquid phase (water) is given by

$$\phi_L = \frac{Q_L}{Q_V} \tag{2}$$

With $Q_L$and Q_v as above.

From the micro motion meter,mass flow rate of the slurry Q_M(Kg/s)

$$Q_M = Q_L \cdot \rho_L + Q_S \cdot \rho_S \tag{3}$$

Where ρ_L and ρ_S = density of liquid and density of solids, respectively(Kg/m^3).

Manipulating (1), (2), and (3) gives:

$$Q_V = Q_L \left(1 + \frac{Q_s}{Q_L}\right) \tag{4}$$

and

$$Q_M = Q_L \left(\rho_L + \frac{Q_S}{Q_L} \cdot \rho_S\right) \tag{5}$$

$$\frac{Q_v}{Q_L} = \frac{1}{\phi_L} \tag{6}$$

From equations (4), (5), and (6) the final form of an equation for determining the solid density in two phase flow is:

$$\rho_S = \frac{Q_M - Q_v \phi_L \rho_L}{Q_v - Q_v \phi_L} \tag{7}$$

In this equation ρ_L is a known quantity and the other parameters are measured using the three meters.

If the density of slurry (ρ_m) is known, either the magnetic or micro motion can be removed and the following equation used in place of equation (7) (13, 14):

$$\rho_S = \frac{1}{Q_L}[(1+Q_L)\rho_M - \rho_L] \tag{8}$$

CONCLUSIONS

. From the above, it is evident that the designed sensor employing magnetic flow meter, micro motion's mass flow meter and a rotating field conductance gauge could provide a radiation free tool to accurately measure the solids tonnage loading at major points in the process.

. For the purpose of verifying the designed solids density sensor it is necessary to conduct a number of performance tests in vertical and horizontal sections of slurry transport lines. Such tests are in the preparation stage.

REFERENCES

[1] Pal R., Rhodes E.: Metering of two phase liquid-liquid flow. Department of Chemical Engineering, University of Waterloo. Waterloo, Ontario

[2] Zimmerman et al., "Fluid Flow Metering Method and System", U.S. patent 3,802,261, 1974.

[3] Schlatter et al., "Fluid Sensing Systems", U.S. patent 3,952,595, 1976

[4] Klempner K.C., Vasiliev A.G., Fiziceskije metody kontrol's zolnosti ugla. Nedra, Moskva 1978

[5] Jardel L., Mirkowshi Cz.: Opracowanie metody i urzadzania do oznaczania zawartosci popiolu w weglach o ziarnistosci powyzej 30 mm. Dokumentacja OBR SMEAG nr 01.5.06.06.01 i nr 01.5.06.06.02. Katowice 1976

[6] Olszowka J., Paul B.: Zasady kontroli jakosci wegla. Wyd. "Slask" Katowice 1972

[7] Gorny W., Guzenda Z., Jardel L: Pomiar gestosei srednieh sortymentow wegla wzastosowaniu do wyznaczania wnich zawartosei popiotu. Mehanizacia i automatyzacja gornictwa. May, 1983

[8] Verbinski V.V., Cassapakis C.G., Lesdernier D.L., Wang R.D.: Three component coal slurry sensor for coal/rock/water concentrations in underground mining operations. Hydrotransport Sixth International Conference on the Hydraulic Transport of Solids in Pipes. September 26th-28th, 1979

[9] Mikhail M.W., Humeniuk O.E., Automatic ash monitor for coal slurries, Energy Research Program. Energy Research Laboratories Report ERP/ERL 19-58 (J,P)

[10] Snell C.H., Dechene R.L., Newton R.E.: Relative volume fraction measurement of gas/liquid or solid/liquid flow with a rotating field conductance gauge. Auborn International Inc. Danvers, Mass., 1979 Patent No. 4063153

[11] Hashmi, K.A., Hamza H.A.: A Mobile Water Treatment Plant for the Coal and Mineral Processing Industries", Proceeding of the 30th Canadian Chemical Engineering Conference, Edmonton, Alberta, October 19-22, 1980

[12] FENCO: Design and development of a fine coal cleaning mobile plant. Department of Supply and Services Canada. January 1985

[13] Syzmanski, J., Mansour, N.: Velocity of Wave Propagation Method For Density Sensing of Coal Water Fuels, Slurries and Emulsions (Manuscript) 1985

[14] Kachelg, C.: The Slurry Monitor TM, A New Development in the Precision Determination of the Density of Slurries Flowing in Pipelines, I.S.A. 1985

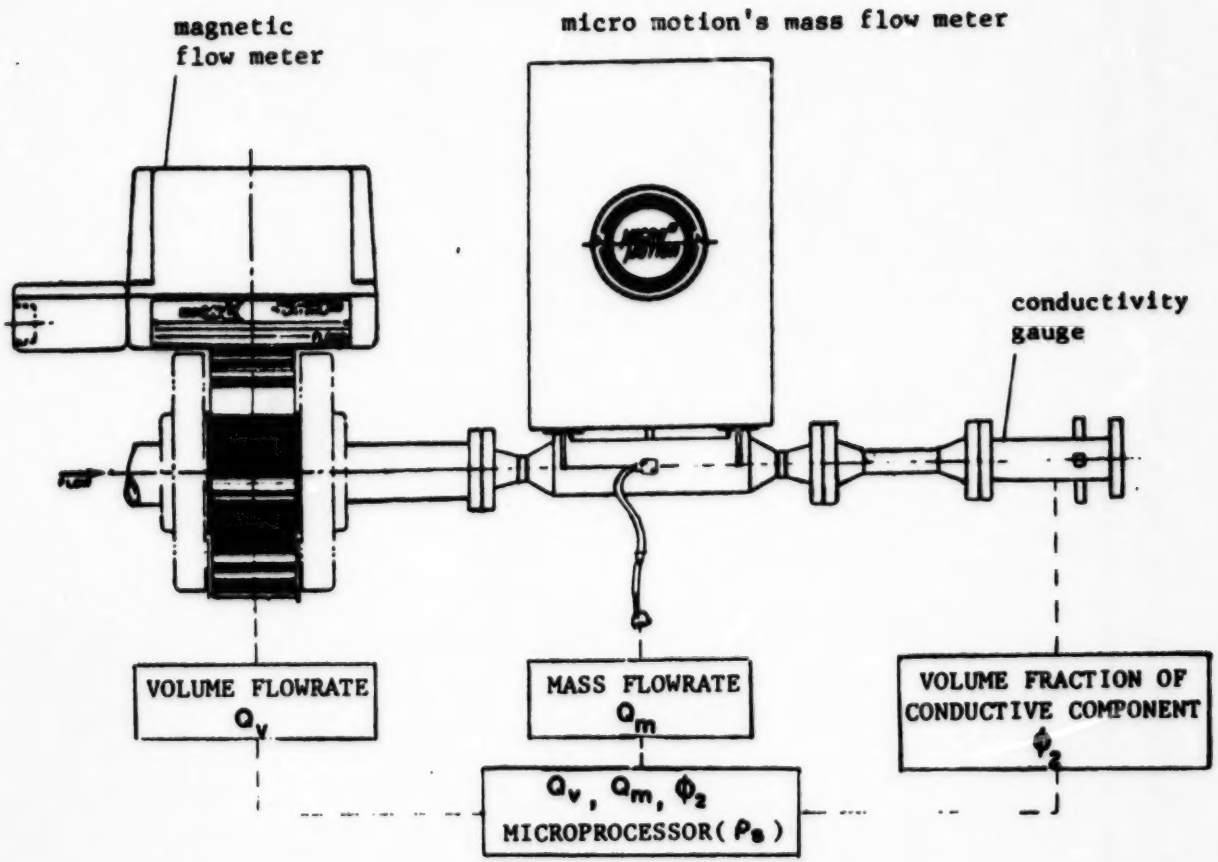

fig.1 schematic diagram of solid density sensor system